DOCUMENT RESUME

ED 309 049 SE 050 698

AUTHOR Blosser, Patricia E.
TITLE Teaching Problem Solving--Secondary School Science. ERIC/SMEAC Science Education Digest No. 2, 1988.
INSTITUTION ERIC Clearinghouse for Science, Mathematics, and Environmental Education, Columbus, Ohio.
SPONS AGENCY Office of Educational Research and Improvement (ED), Washington, DC.
PUB DATE 88
NOTE 4p.; For other 1988 science digests see SE 050 697-699.
AVAILABLE FROM ERIC/SMEAC, The Ohio State University, 1200 Chambers Road, 3rd Floor, Columbus, OH 43212 ($1.00 single copy; ordered in sets by year and area, $3.00).
PUB TYPE Information Analyses - ERIC Information Analysis Products (071) -- Information Analyses (070)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Academic Achievement; Biology; Chemistry; *Cognitive Development; Educational Development; Educational Research; *Educational Strategies; Literature Reviews; Physics; *Problem Solving; Science Activities; Science Education; Secondary Education; *Secondary School Science; Teaching Methods; Technology

ABSTRACT

Problem solving is often identified as a goal of science education. What is considered problem solving varies from teacher to teacher. The ultimate goal of problem-solving education has been identified as a means of helping students develop higher-order thinking skills. This ERIC digest focuses on problem solving in secondary school science as illustrated by research studies found in the literature for 1982-88. The digest discusses: the importance of problem solving instruction; problem solving research in biology, chemistry and physics; and implications of problem solving research for science teachers. Seventeen references are included. (CW)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

X This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

Robert W. Howe

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

ED309049

Teaching Problem Solving - Secondary School Science.

ERIC/SMEAC Science Education Digest No. 2, 1988.

Patricia E. Blosser

ERIC Clearinghouse for Science, Mathematics,
and Environmental Education
Columbus, Ohio

SE050 698

ERIC

Clearinghouse for Science, Mathematics, and Environmental Education

1200 Chambers Road, Third Floor
Columbus, Ohio 43212
(614) 292-6717

ERIC/SMEAC Science Education Digest No. 2, 1988

TEACHING PROBLEM SOLVING — SECONDARY SCHOOL SCIENCE

This digest is focused on problem solving in secondary school science classes, as illustrated by research studies found in the literature for 1982-88.

Problem Solving: Why is it Important?

Helping students develop problem solving skills is a frequently-cited goal of science educators. The National Science Teachers Association (NSTA), in its 1980 position statement, urged that science in the schools should result in the development of scientifically literate people able to use science knowledge in everyday decision-making. To achieve this goal, NSTA advocated that science teachers help students learn and think logically, specifying that ". . . high school laboratory and field activities should emphasize not only the acquisition of knowledge, but also problem solving and decision making" (1985:48).

Problem solving means many things to many people. For some, it includes an attitude or predisposition toward inquiry as well as the actual processes by which individuals attempt to gain knowledge. Usually, when teachers discuss problem solving on the part of pupils, they anticipate pupils will become involved with the thinking operations of analysis, synthesis, and evaluation (considered as higher-level thinking skills). The American College Testing program has redesigned its college admissions test with a new emphasis on assessing higher-order thinking skills (EdLine, 1989).

What constitutes a problem? ". . . Whenever there is a gap between where you are now and where you want to be, and you don't know how to find a way to cross that gap, you have a problem." (Hayes, 1981:i) Some people consider end-of-chapter questions or activities as problems, but Bodner contends that if an individual knows what to do when reading a question, it is an exercise (something done for practice) and not a true problem (1987:513).

What Characterizes Problem Solving Research in Science Education?

Good and Smith (1987:31-36) provided a summary of problem solving research in science education. They wrote that, in the 1960s, research on problem solving was focused on how people solve puzzles and games. In the early 1970s, science education researchers tape recorded "think aloud" interviews to gather data. Current research on problem solving in science education involves information processing theory - the idea that solving a problem requires two processes: retrieval from memory of the pertinent information and proper application of the information to the problem. Research studies now published are frequently comparisons of expert and novice problem solvers, in physics, biology, and chemistry.

Good and Smith consider the study of problem solving in science education to still be in its infancy. They suggest two main questions relative to students' science problem solving: (1) how do students go about solving problems? (2) what instructional techniques improve students' problem solving skills? They consider that more research related to question one has been published than that related to question two (1987:32).

The focus of problem solving research in science varies with the discipline. The following studies are some representative examples, grouped by biology, chemistry, and physics.

Problem solving research in biology. Most of the problem solving research in high school biology involves teaching genetics. In a recent article on teaching genetics, Stewart discussed ways different problem types may contribute differentially to learning outcomes (1988:237). Stewart contends there are two main types of thinking involved in solving genetics problems: (1) reasoning from causes to effects, and (2) reasoning from effects to causes. Most high school or introductory college textbook genetics problems are cause to effect, with the difficulty of the problem varying with genetics content and wording. Such problems require content-specific algorithms. Cause to effect problems do not provide students with insights into the nature of science. However, effect to cause problems can be developed if computer-generated information is provided. The most important insight that students may gain from solving effect to cause problems may be the outcome of understanding science as an intellectual activity (1988:243-251).

Problem solving research in chemistry. Chemistry courses and textbooks appear to focus on quantitative problems. There is interest in how chemistry students solve quantitative problems and also in the effects of different instructional strategies on students' success in problem solving. Many research reports are focused on the use of algorithms, ". . . rules that can be followed more or less automatically by reasonably intelligent systems. . ." (Bodner, 1987:513).

Nurrenbern and Pickering (1987:508-510) worked with five different general chemistry classes, at two different institutions, in which students were given examinations with "traditional questions" (could be answered using algorithmic strategies) and multiple-choice questions with no mathematics content but which required conceptual understanding of chemistry content for correct solution. Students had far greater success in answering "traditional" questions than in answering the concept questions.

Problem solving research in physics. Research in physics has gone in two directions: information processing research concerned with observable and measurable steps in problem solving and research in constructing solutions in which investigators are concerned with the internal cognitive processes that result in these steps (Omasta and Lunetta, 1988:625). Much of the research on concepts and conceptual change in physics had been conducted against a background of problem solving in which pupils worked on problems found in the back of the textbook (Watts, 1988:74-79). Since this problem solving research has begun, there has been a shift in education from didactic work to participative group work, requiring a wide range of teaching methods. Watts believes that problem solving is underwritten by at least two major assumptions: (1) constructing a mental model of what needs to take place in order to achieve whatever goal is set and (2) the transfer of cognitive content and skills. Therefore, Watts concludes, conceptual change and problem solving go hand in hand.

What are Some Implications of Problem Solving Research in Science?

Problem solving is identified as a top priority in many curricula in science. Teachers are not trained to teach problem solving. In addition, problem solving strategies involve formal operational skills such as proportional reasoning, logical-deductive thinking. Science education researchers report that 50 percent of college chemistry students are not formal operational, so it seems logical to conclude that most high school students do not operate at this level (Powers, 1984:63).

McDermott and the Physics Education Group at the University of Washington have investigated how students learn physics. They report that many students emerge from their study of physics or physical science without a functional understanding of some elementary but fundamental concepts. The problem exists at all levels of education and is particularly distressing because it means that precollege teachers have not developed sound conceptual understanding of the material they are expected to teach (McDermott, 1984:31).

McDermott has identified some implications for instruction:

> If the development of conceptual understanding is a primary goal, then instruction must reflect this priority. The amount of material covered in introductory courses must of necessity be reduced. Experience has shown that merely presenting the correct information, either orally or in written form, is seldom effective in helping students overcome misconceptions. Specific difficulties must be directly addressed. Because many relationships implicitly assumed by physicists are not obvious to students, teachers need to help students make explicit connections among physical concepts, their mathematical representations, and the physical world. Qualitative questions that probe for conceptual understanding must be included in homework assignments, in laboratory reports, and especially on examinations. It is vital to adopt such an approach in the preparation of teachers, if they are to acquire the competence necessary to foster conceptual development in their students (1984:32).

While students' naive ideas or preconceptions may interfere with their understanding of science concepts and thus influence their problem solving, math anxiety may also handicap students. Gabel and Sherwood investigated the effectiveness of four instructional strategies for teaching problem solving to students of various proportional reasoning abilities, visual and verbal preferences, and levels of math anxiety. They suggested that teachers need to incorporate teaching strategies into lessons to reduce the level of students' mathematics anxiety. Students with high levels of anxiety and the absence of another aptitude (visual preference or proportional reasoning ability) profit by methods containing supportive material that is not mathematical in nature. Teachers should use supplemental materials, less mathematics, and more visual approaches with high math-anxious students also deficient in proportional reasoning ability or with low visual preference (1983:175).

Staver, after studying the effects of problem format and number of independent variables on the responses of students to a control of variables reasoning task, found that more independent variables, more pieces of information, more steps necessary to solve the problem resulted in a decline of student success rate. Staver suggested that teachers need to use methods of instruction and evaluation that reduce the overload on working memory as such ideas are introduced and evaluated (1986:535-541).

Ronning, McCurdy, and Ballinger point out that teachers need to consider more than problem solving methods and the degree of knowledge acquisition involved in problem solving. They also need to consider individual differences among problem solvers. Field independent students, in the Ronning et al study, solved more problems than did field dependent students. It is possible that field dependent students might benefit from carefully structured instruction with clearly defined objectives because the students seemed unable to bring past experience (knowledge) to bear on tasks, as well as being unable to analyze the tasks (1984:80).

Sometimes difficulties in problem solving may be caused by the sequencing of instruction. Tolman said that the topic of meiosis usually precedes, and is separated from, textual material on genetics. Genetics is usually introduced with a discussion of Mendel's work on peas, with no bridge between genetics and meiosis (1982:525-27).

Teachers need to be aware of the difference between "successful" and "meaningful" performance. Stewart has provided an example of this in genetics. Students could define most concepts (successful performance) but had difficulty in describing how the concepts related. Students with meaningful performance could explain, in terms of genetics, *why* they carried out each step in solving genetics problems. Stewart suggested biology teachers need to tie algebraic methods to meiosis if meaningful problem solutions are to be reached (1982:81,89).

Stewart's example related to the finding of Nurrenbern and Pickering about conceptual learning in chemistry. These investigators stated, "Most educators see solving chemistry problems to be the major behavioral objective for freshman chemistry. Textbooks are written from this point of view, and this may be what establishes the supreme importance of numerical problems in student minds. . . ." Chemistry teachers need to keep in mind that solving problems is not equivalent to teaching pupils about the nature of matter (1987:509).

Technology is being used to teach problem solving. Powers (1984:13-19) described a computer-assisted problem solving method for use with beginning chemistry students. Krajcik et al. (1988:147-155) described several preliminary studies involving students interacting with genetics and with the molecular structure of gases. Group and individual patterns of how students learned concepts and applied problem solving strategies were compared. Such research should provide guidance to classroom teachers about the use of technology and the design of curriculum and instruction.

REFERENCES

Bodner, George M. "The Role of Algorithms in Teaching Problem Solving." *Journal of Chemical Education* 64(6):513-514, June, 1987.

Gabel, Dorothy L. and Robert D. Sherwood. "Facilitating Problem Solving in High School Chemistry." *Journal of Research in Science Teaching* 20 (2):163-177, 1983.

Good, Ron and Mike Smith. "How do we Make Students Better Problem Solvers?" *The Science Teacher* 54(4):31-36, April, 1987.

Hayes, John R. *The Complete Problem Solver*. Philadelphia, PA: The Franklin Institute Press, 1981.

Krajcik, Joseph S., Patricia E. Simmons, and Vincent N. Lunetta. "A Research Strategy for the Dynamic Study of Students' Concepts and Problem Solving Strategies Using Science Software." *Journal of Research in Science Teaching* 25(2):147-155, 1988.

McDermott, Lilian C. "Research on Conceptual Understanding in Mechanics." *Physics Today* 37:24-32, July, 1984.

National Science Teachers Association. "Science-Technology-Society: Science Education for the 1980s," in *NSTA Handbook 1985-86*. Washington, DC: National Science Teachers Association, 1985, pp. 46-49.

"New ACT Test to Stress Higher-Order Thinking Skills," *EdLine*, January 4, 1989.

Nurrenbern, Susan and Miles Pickering. "Concept Learning vs. Problem Solving: Is There a Difference?" *Journal of Chemical Education* 64(6):508-510, June, 1987.

Omasta, Eugene and Vincent N. Lunetta. "Exploring Functions: A Strategy for Teaching Physics Concepts and Problem Solving." *Science Education* 72(5):625-636, 1988.

Powers, Michael H. "A Computer Assisted Problem Solving Method for Beginning Chemistry Students." *The Journal of Computers in Mathematics and Science Teaching* 4(1): 13-19, Fall, 1984.

Ronning, Royce R., Donald McCurdy, and Ruth Ballinger. "Individual Differences: A Third Component in Problem-Solving Instruction." *Journal of Research in Science Teaching* 21(1):71-82, 1984.

Staver, John R. "The Effects of Problem Format, Number of Independent Variables, and Their Interaction on Student Performance on a Control of Variables Reasoning Problem." *Journal of Research in Science Teaching* 23(6):533-542, 1986.

Stewart, James H. "Difficulties Experienced by High School Students When Learning Basic Mendelian Genetics." *The American Biology Teacher* 44(2):80-84, February, 1982.

Stewart, Jim. "Potential Learning Outcomes from Solving Genetics Problems: A Typology of Problems." *Science Education* 72(2):237-254, April, 1988.

Tolman, Richard R. "Difficulties in Genetics Problem Solving." *The American Biology Teacher* 44(9):525-527, December, 1982.

Watts, Mike. "From Concept Maps to Curriculum Signposts." *Physics Education* 23(2):74-79, March, 1988.

Prepared by Patricia E. Blosser
Associate Director, User Services

OERI
Office of Educational Research and Improvement U.S. Department of Education

This digest was prepared pursuant to a contract with the Office of Educational Research and Improvement, U.S. Department of Education. Contractors undertaking such projects under government sponsorship are encouraged to express freely their judgment in professional and technical matters. Points of view or opinions, however, do not necessarily represent the official views or opinions of the Office of Educational Research and Improvement.